INSTRUCTION MANUAL

REGATRON

POWER SUPPLY

MODEL C612HL

SERIAL No. 1387

FET test set

ELECTRONIC
MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

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REGATRON CONSTANT-CURRENT PROGRAMMABLE POWER SUPPLY

MODEL C612AL

SERIAL No. 1387

Programming Constant _____ umhos/ma

CODE D962

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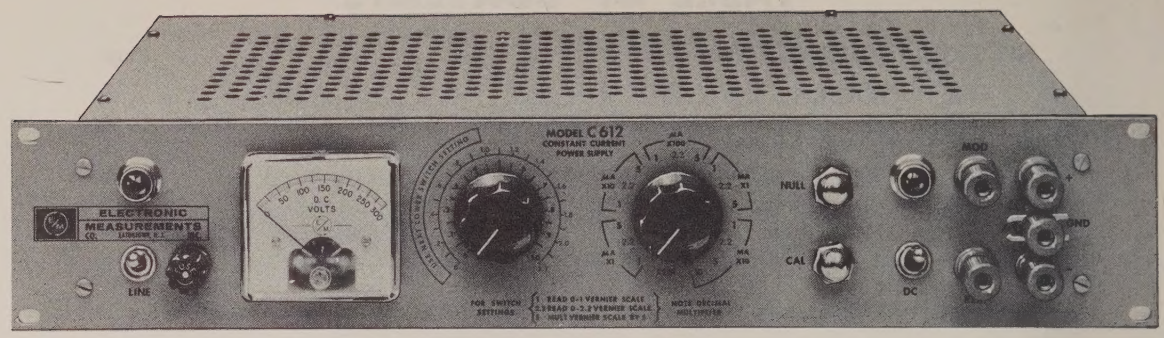


Figure 1-1. Regatron Constant-Current Power Supply.

SECTION 1
DESCRIPTION

1-1. GENERAL. This Regatron* Constant-Current Power Supply (figure 1-1) provides constant dc output in 16 selected ranges. Within each range, the output current is continuously adjustable from zero to the maximum range setting. In addition, the output current can be controlled remotely, or programmed.* Voltage compliance is shown graphically in figure 1-2. Additional detailed data is given in the Table of Specifications, paragraph 1-3.

1-2. APPLICATION. This power supply is capable of serving a wide variety of laboratory, production, and system applications in which a constant-current, programmable dc power source is a requisite. Semiconductor applications include measurement of peak inverse voltage of solid state junctions, transistor leakage measurement, testing of reference diodes for voltage ratings and dynamic impedance, and employment of dc potential source for transistorized circuits. Constant-current power supplies are also being utilized for ampere-turn control in the generation of magnetic fields, in testing relays, and as power sources for dc gyromoters and torquers requiring precise rpm control. Further applications include checking of gas tubes for operating voltage, calibration of dc ammeters, arc production in gaseous breakdown devices, accurate charging of batteries, and electrolytic capacitor film forming.

1-3. TABLE OF SPECIFICATIONS.

NOTE

All specifications apply with the Current control set at maximum (fully clockwise) position.

Constant-Current Output	Model C612: 1.0 microampere to 100 milliamperes. Model C624: 2.2 microamperes to 220 milliamperes.
Current Regulation	Line: 0.15% for 105- to 125-volt or 198- to 242-volt line change. Load: 0.1% for no load to full load, except 0.2% on 1- and 2.2-microampere current ranges.
Ripple and Noise Current	0.03% rms of Range Selector setting plus: Model C612: 0.5 microampere negative ground, 0.1 microampere positive ground, or 0.2 microampere floating ground. Model C624: 0.7 microampere negative ground, 0.15 positive ground, or 0.25 floating ground.
Stability of Standard Version	0.3% of Range Selector setting using internal controls under fixed line, load, and temperature conditions for 8 hours after warmup. 0.15% with same conditions using suitable external high stability programming

* Registered U. S. Patent Office. Patents issued and pending.

ELECTRONIC MEASUREMENTS COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

INSTRUCTION SHEET #108
MAY 1963

CHECKING OUT AND TROUBLE-SHOOTING SERIES C600 CONSTANT-CURRENT POWER SUPPLIES

This write-up is primarily for the purpose of E/M final electrical inspectors. It is designed to get a constant-current unit operating that has never been operating before. However, it can be used as a guide for repairing constant current units that were previously operational.

A. PRELIMINARY EXAMINATION

1. Examine the unit for obvious defects; that is, wires not soldered, components broken or improperly assembled, and so on.
2. Remove all removable tubes and transistors and turn LIMITER control potentiometer to maximum.
3. Plug ac line into an ac power source that is controlled by a variac that is set for zero volts.
4. Turn variac to 5 volts ac.
5. Turn ac and dc switches on.
6. With a multimeter, check voltages across all electrolytic capacitors to make sure that they are wired properly. For those units that have a TDR, it will be necessary to actuate the TDR manually to check the voltages across the screen voltage capacitor and the main power capacitor. Care must be exercised with high voltage units, as dangerous voltages can be developed with this very low line voltage. Make necessary corrections and proceed to step 7.
7. Turn variac to 125 volts ac. Units with TDR must be allowed time for TDR to actuate.
8. Measure the voltage across all electrolytic capacitors for:
   (a) Proper voltage.
   (b) To make sure that none of the electrolytics are operating above rating.

B. FILAMENT REGULATOR

1. Plug the 2N1372 transistors into the filament regulator section. These are 25 volt, PNP, Mediam Beta transistors. (Any similar transistors may be used if the 2N1372's are not available.)
2. Plug in the 12AY7 error detector (input) tube.
3. Put a dc voltmeter across the filament regulator. This would be from collector of EM 101, diamond-shaped transistor, to pin 9 of the 12AY7 (see previous step).
4. Turn ac of unit on and set variac to 105 volts ac. Dc voltage should be about 10 volts $\pm\frac{1}{2}$ volt (if not, change dc voltmeter from pin 9 of 12AY7 to pin 4 or 5 of 12AY7).

CHECKING OUT AND TROUBLE-SHOOTING SERIES C600 CONSTANT-CURRENT POWER SUPPLIES (cont'd)

5. Turn variac to 125 volts ac. Voltage should rise to about 12.5 ±½ volt dc.
6. If voltage is different, check wiring from dc connections to the filter of the filament regulator of the dc voltage. If necessary, make corrections and proceed to step 7.
7. Put dc voltmeter across filament of 12AY7. This would be pin 9 and 4 or 5 of the 12AY7.
8. Adjust voltage for 5.8 to 6.0 volts dc. If adjustment can't be made, proceed as follows:
   (a) Remove one end of the 30 ohm resistor in parallel with the EM101 transistor.
   (b) Remove two 2N1372 transistors. The filament voltage should fall to zero. If it doesn't check the filament regulator section for proper assembly, and the EM101 for short.
   (c) Replace the first driver transistor. The filament voltage should rise to maximum input voltage. If not, check the first driver transistor.
   (d) Replace second 2N1372. If regulator doesn't operate, check second 2N1372. After making necessary corrections, and adjustments, proceed to step 9.
9. Vary line voltage from 105 to 125. Regulator voltage should not vary more than 100 millivolts.
10. Turn constant-current unit off.

C. POSITIVE AND NEGATIVE SUPPLY VOLTAGES

If unit has a chopper stabilizer, remove chopper module and place short between pin 5 and pin 6 of chopper socket.

1. Plug in all of the gas regulator tubes. For the C612 and C624 there are three... two OA2's and one 85A2. For all others there are five. Two OA2's, two OB2's and one 85A2.
2. Turn ac on.
3. Check to make sure that all of the VR tubes are glowing. Vary the line voltage from 100 volts ac to 130 volts ac and check to make sure that none of the VR tubes extinguish.
4. If any tubes are not glowing, one of the following is probably the reason:
   (a) Glow tube has an extra high starting voltage. Check voltage drop across this tube. If higher than normal operating voltage, replace the glow tube.
   (b) There could be a wiring error such that a glow tube is partially or completely shorted. The voltage across the glow tube will be lower than normal operating voltage. This extra current drain must be found.
   (c) The pc socket is not properly soldered. Check voltage across the tube from copper side of pc board. Check voltage across tube by removing tube and putting probe into the pin holes. If the voltages do not match, chances are the dc socket is not soldered in properly
5. Turn ac off and make necessary corrections.

CHECKING OUT AND TROUBLE-SHOOTING SERIES C600 CONSTANT-CURRENT POWER SUPPLIES (cont'd)

D. PRELIMINARY BALANCE OF AMPLIFIER

1. Turn range switch to REM position. If unit is fully programmable, this step is not necessary.
2. Connect jumper between positive output terminal and REM terminal.
3. Connect jumper between negative output terminal and MOD terminal.
4. Plug in the two 2N2191 amplifier transistors.
5. Connect a dc voltmeter between input grid of the next stage (this would be pin 1 of the 6AU6 on all units but the C638, and on the C638 it is pin 4 of the 6842) and the remote terminal. This is accomplished by putting a probe into the proper location in the tube socket and the other probe of the voltmeter on the REM terminal.
6. Turn ac on.
7. After warm-up, rotate the NULL potentiometer from maximum to minimum. The voltage (see step 5) should vary from about -70 volts dc to about -100 volts dc. If it doesn't, there are problems in the input stage and the transistor amplifier stage. Make the following checks:
   (a) Check to see that the sockets of these components are soldered in properly. This can be done by removing the 12AY7 tube and the two 2N2191 transistors, and making a point to point check between socket and pc copper.
   (b) Wiring from the NULL potentiometer to the pc board is not correct.
   (c) Wiring from the grids of the 12AY7 to the MOD and negative output terminal is not correct.
   (d) The one or both of the 2N2191 transistors are defective.
   (e) The 830K and/or 330K collector resistors of the 2N2191 transistors are not of proper value.
   (f) One or more of the 22K resistors in the plates and emitters of the 12AY7 and the two 2N2191 transistors are not correct. Turn ac off and make necessary corrections and proceed to step 8.
8. Plug in the next amplifier tube (6AU6 in all units but C638, C638 uses a 6842).
9. Connect the dc voltmeter between the REM terminal and plate of 6AU6 (6842 in C638).
10. Turn ac on and wait for warmup
11. Vary NULL potentiometer from maximum to minimum. Voltmeter should vary from about -40 volts dc to +150 volts dc. This variation should occur over a very small range of NULL potentiometer rotation.
12. If this does not happen there is trouble in the 6AU6 (6842 in C638) amplifier stage. This could be one of the following:
   (a) Tube socket not properly soldered.
   (b) Wrong plate resistor.
   (c) Wrong screen grid divider resistors.

   Turn ac off and make necessary corrections and proceed to step 13.
13. For those units having a cathode follower between the final

CHECKING OUT AND TROUBLE-SHOOTING SERIES C600 CONSTANT-CURRENT POWER SUPPLIES (cont'd)

amplifier and the series dropping tubes, plug the 12AX7 cathode follower in.

14. Connect a dc voltmeter between REM terminal and the cathode of the 12AX7 cathode follower.
15. Turn ac on and wait for warmup
16. Rotate NULL potentiometer from maximum to minimum. Voltage should vary from about -40 volts dc to about +150 volts dc. This variation should occur over a very short rotation of the NULL potentiometer.
17. If this does not happen, there is trouble in the 12AX7 cathode follower. This could be one of the following:
    (a) Wiring error... check out all associated wiring.
    (b) Wrong components.
    (c) Bad 12AX7 tube.

Turn ac off, make necessary corrections and proceed to step 18.

18. Remove jumper from positive output to REM terminal.
19. Plug in one of the series tubes.
20. If unit has no meters, put voltmeters between positive output terminal and REM terminal.
21. Turn ac on and wait for unit to warm up (on C638 set input voltage control to about 300).
22. Rotate NULL potentiometer from maximum to minimum. Output voltage should vary from 0 or slightly negative to the maximum capability of the unit.
23. If unit does not operate in this manner, trouble is in series deck and wiring. It could be one of the following:
    (a) Bad dc fuse.
    (b) Bad series tube.
    (c) Improper wiring.
    (d) Wrong component.
    (e) Poor solder joints.

Turn ac off, make necessary corrections and proceed to step 24.

24. Put in all series tubes and repeat steps 18 through 23.

Turn ac off, make necessary corrections, remove all jumpers from output terminals and proceed to the next section.

E. PRE-TEST

1. Set unit for 10 ma of operation.
2. Put jumper between positive and negative output terminals.
3. Put bucking meter between negative output terminal and MOD terminal.
4. Turn ac on and wait for warmup
5. Turn dc on and adjust NULL control for zero on bucking meter.
6. Turn dc off.
7. Turn vernier control to maximum.
8. Place voltage checking device (high impedance ½% accuracy equipment) between REM terminal and MOD terminal.
9. Adjust CAL control for 5.0 volts dc.

CHECKING OUT AND TROUBLE-SHOOTING SERIES C600 CONSTANT-CURRENT POWER SUPPLIES (cont'd)

10. Replace jumper from positive and negative terminals with an ammeter. A multimeter should be adequate.
11. Turn dc on and check all current ranges for correct values of current. This is to check out the range switch for proper construction and location of parts. The unit is now ready for final checks.

F. VOLTAGE LIMITER

1. Check wiring of limiter, particularly LIMITER potentiometer and CAL potentiometer.
2. Plug in limiter components, two transistors of type 2N398 or 12AX7 and one 2N398.
3. Remove all loads from output terminals of unit.
4. Turn ac of unit on and wait for warmup.
5. Turn dc on.
6. Voltage should go to maximum.
7. Slowly turn LIMITER control towards zero.
8. Voltage should start dropping off by the time potentiometer has reached 90 degrees of rotation.
9. Rotate potentiometer 2/3 of the way down. If voltage has not dropped, something is wrong with limiter. If there are problems, it is probably one of the following:
   (a) Reference resistor not installed.
   (b) Diode switch between 6AU6 grid and collector of limiter transistor is not operating.
   (c) Limiter transistor is bad.

Turn unit off and make necessary corrections and recheck, and proceed to step 10.
10. After limiter is operating for dc, check for oscillations.
11. It may be necessary to change the capacitor across the collector resistor of the limiter transistor, or,
12. Put in a capacitor between positive output and arm of control potentiometer or,
13. Put in a capacitor between positive output and collector of transistor that drives 6AU6.

G. CHOPPER-STABILIZER

After unit is operating properly, proceed as follows:
1. Remove short from pins 5 and 6 of chopper socket.
2. Check wiring to make sure the 120K resistor and extra 20 microfarad, 25 volt capacitor is in.
3. Plug in chopper module. Plug into module the 12AX7 tube and mechanical chopper.
4. Turn ac on and wait for warmup.

CHECKING OUT AND TROUBLE-SHOOTING SERIES C600 CONSTANT-CURRENT POWER SUPPLIES (cont'd)

5. Place ammeter between positive and negative terminals.
6. Set unit for 10 ma operation.
7. Place a bucking meter between negative output and arm of vernier.
8. Turn dc on and vernier to maximum.
9. Wait a few minutes until chopper has settled and check current. It should be very near the 10 ma.
10. Check bucking meter. It should be near zero.
11. Rotate NULL potentiometer back and forth. Bucking meter should show abrupt change but should return to within a few mv of original position.
12. The only probable things that might be wrong are:
    (a) A bad mechanical chopper.
    (b) A bad 12AX7 tube.
    (c) Bad filter capacitor in chopper module.
    (d) Improper wiring.

After unit has been checked, remove chopper module, replace short between pins 5 and 6 of chopper socket, and reset NULL for zero on bucking meter, and then remove the short and replace the module. The unit should always be operating with a minimum outut from the chopper.

INCORPORATION OF VOLTAGE LIMITER IN REGATRON CONSTANT-CURRENT POWER SUPPLIES

The purpose of a voltage limiter on a constant-current power supply is to permit control of the voltage applied to the load, that is, to prevent an uncontrolled rise in voltage above a particular value. A constant-current power supply, by definition, holds load current constant, but increases its voltage to the load as the load resistance rises. In many applications it is desirable to limit the available voltage at some particular value, and this is the function performed by the limiter. It should be noted, however, that with the voltage limiter adjusted to a particular value, a rise in load resistance above a certain point, namely the "knee of the EI curve", will result in a decrease in current from the output setting of the power supply. Above this point, in effect, the power supply reverts to constant-voltage, but with only moderate regulation. In general, the quality of the amplifiers within the regulator of the supply determines the sharpness of the knee.

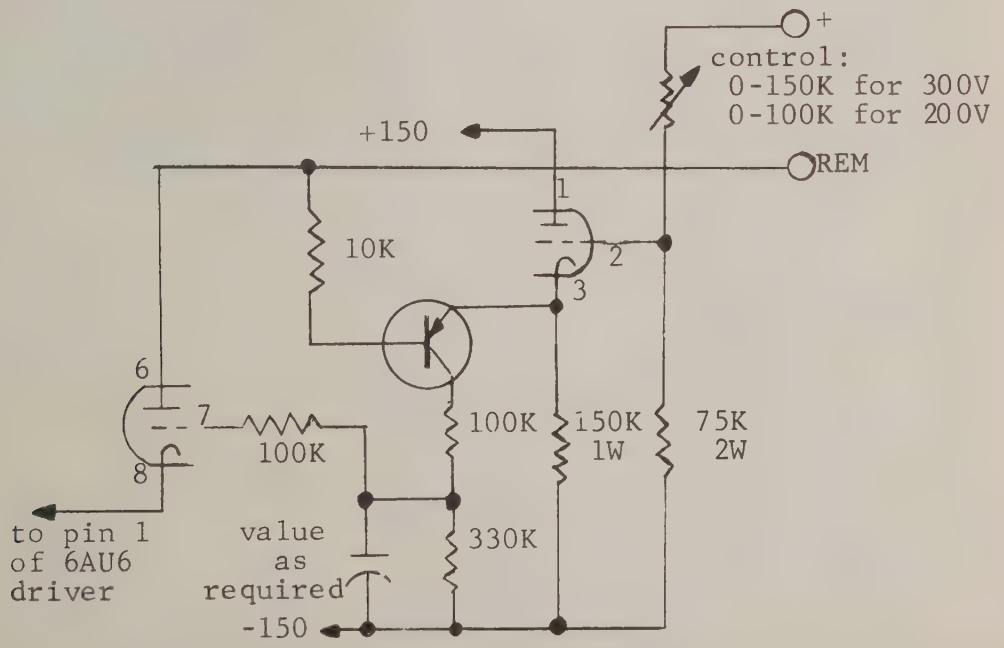


Figure 1. Voltage limiter for Regatron Constant-Current Power Supplies.

CIRCUITRY. (See Figure 1.) The voltage limiter incorporates a bridge-like sensing configuration similar to that utilized in Electronic Measurements voltage-regulated power supplies. The potentiometer in Figure 1 then performs the function of voltage limiter control, and the 75K resistor is the reference resistor and is adjusted for proper maximum voltage. The control grid, pin 2, of one section of the 12AX7 tube, connected as a high input impedance cathode-follower, is at the junction of the two resistors. The signal at the cathode, pin 3, follows the voltage fluctuations sensed at the grid in an almost 1:1 correspondence, and this signal is applied at the emitter of the PNP transistor. The base of the transistor is connected to the REM terminal of the power supply through a 10K current limiting resistor. The transistor compares the voltage at the REM terminal with the voltage sensed at the junction of the limiter control and fixed reference resistors. The resultant collector signal is applied to the grid of the second section of the tube, the cathode-follower output of which goes to the control grid of the 6AU6 high gain amplifier of the power supply.

When output voltage is below the limiter setting, the sensed voltage applied to the emitter of the transistor is negative with respect to the voltage at the base, which is at REM terminal potential, and the transistor is therefore turned off. In this condition the second cathode-follower tube section is turned sufficiently off so that it has no effect on the 6AU6 driver amplifier.

When output voltage rises to the limiter setting, the sensed voltage applied to the emitter becomes more positive with respect to the base of the transistor. The transistor is thereby turned on and, by the same signal path described before, takes control of the 6AU6 driver amplifier, driving the power supply regulator system to equilibrium at the voltage limiter setting.

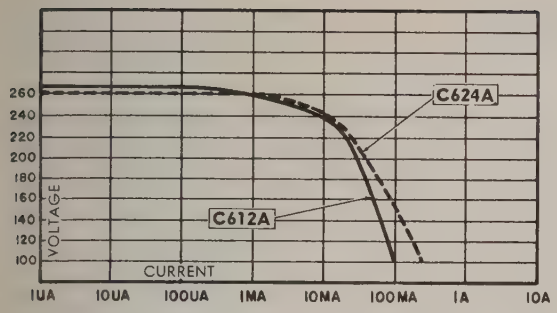


Figure 1-2. Voltage compliance, maximum voltage available at various output current settings.

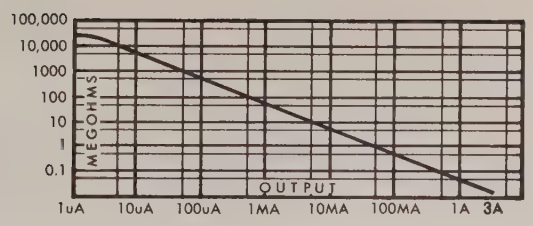


Figure 1-3. Internal Impedances at various output current settings.

	resistor in place of internal controls.
Stability of Chopper Stabilized Version	0.2% of Range Selector setting using internal controls with same conditions as above. 0.08% with same conditions using suitable external high stability programming resistor.
Voltage Limiting	Optional. Range of voltage limiter is from zero volts to maximum compliance shown in figure 1-2.
Transient Response	For step change from zero to 100 volts or 100 to zero volts, output current recovers to within regulation limits in less than 1.0 millisecond.
Programming Constant	See title page.
Internal dc Impedance	See figure 1-3.
Output Polarity	Swinging link permits positive or negative ground, or floating output.
Modulation Input	Bandwidth 10 kc. MOD input impedance 5000 ohms. Permissible modulation signal plus dc potential at MOD grid is 8 volts maximum, and modulation must never cause output to exceed voltage compliance and load current rating.
Overload Protection	Input ac line fused. Unit can be operated safely with short circuit load.

NOTE

An open load circuit for a constant-current supply is analogous to a short circuit for a voltage regulated supply and, although repeated opens are not advisable, no damage to the power supply will result.

Input Power Requirements	105 to 125 volts ~~or 198 to 242 volts~~, 50 to 60 cps, single-phase. 150 watts input at full load for Model C612; ~~175 watts input at full load for Model C624~~.
Terminations	Front: Universal insulated binding posts. Rear: Barrier-type terminal strip (optional). Line Cord: 3 - conductor type.
Finish	Smooth gray semi - gloss enamel Class 2 per MIL–E–15090. Black and red panel designations.
Mounting	Unit fits standard 19-inch rack and is equipped with rubber feet for table top mounting.
Dimensions	3-1/2 inches high, 19 inches wide, 9-1/2 inches deep.
Weight	16 pounds, approximately.

1-4. STANDARD VERSIONS. This Regatron power supply is available in any of several standard versions: metered or unmetered; with or without panel controls; with rear, or front and rear terminations; with or without voltage limiting; and with or without chopper stabilizer. This instruction manual is essentially applicable to all of these standard versions.

SECTION 2
OPERATION

2-1. INSPECTION. Immediately upon unpacking the power supply, perform a visual inspection for internal or external damage incurred in shipment. If damage is discovered, follow the Claim For Damage in Shipment instructions on the Warranty, located on the front inside cover of this instruction manual. Prior to placing the power supply in operation for the first time, make certain that all shipping blocks have been removed from inside the unit, and check to see that all electron tubes and transistors are securely seated in their sockets.

2-2. INSTALLATION. This power supply operates on 105 to 125 volts or 198 to 242 volts, 50 to 60 cps, single-phase power. It may be placed on a table or mounted in a standard 19-inch rack. Sufficient clearance should be provided above and below the power supply to provide adequate ventilation. The top and bottom covers may be removed to increase ventilation when required by ambient conditons.

2-3. CONTROLS AND FUSE. The following controls and fuse are located on the front panel of the power supply (see figure 1-1):

LINE switch	Controls application of ac power input to power supply.
LINE fuse	Protects primary input circuit against overloads.
CAL screwdriver adjust control	Adjusts output current to comply with Range Selector switch and Current control settings. (Refer to paragraph 4-3.)
NULL screwdriver adjust control	Adjusts balanced input detector to null or zero level. (Refer to paragraph 4-2.)
DC switch	Controls application of constant-current output of power supply.
Range Selector switch	Selects one of 16 output current ranges or remote operation.
Current control	Adjusts output current from zero to maximum range setting.
LIMITER VOLTS (optional)	Controls maximum voltage available to load.

2-4. OPERATION. Do not operate the power supply before reading paragraphs 2-5, 2-6, and 2-7. Proceed as follows to place the unit in operation:

a. Check to see that the LINE and DC switches are set to the off (down) position.

b. Plug the line cord into the ac power outlet.

c. Set the LINE switch to the on (up) position. The green indicator lamp should light.

d. Connect a load between the + and — output binding posts. Refer to paragraph 2-6 for necessary precautions.

e. Select the desired output current range. Refer to paragraph 2-5 for considerations in selection of the current range.

f. Check to see that the Current control is set below the required current value.

g. Set the DC switch to the on (up) position. The red indicator lamp should light.

h. Set the Current control to the desired current. The panel Voltmeter will indicate the voltage across the load, less the voltage drop across the internal sample resistor.

2-5. SELECTION OF CURRENT RANGE, PREFERRED METHOD. In performing steps e and h, paragraph 2-4, it is preferable to use the lowest Range Selector switch setting consistent with the desired output current, maintaining the Current control setting at the high end of the scale.

For example, with the Range Selector switch set at MA X10 5, a required output of 16 milliamperes would place the Current control setting at the low end of the scale, which is labeled USE NEXT LOWER SWITCH SETTING. It would then be advisable to set the Range Selector switch at MA X10 2.2 and obtain the 16 milliamperes output with the Current control set at the high end of the scale.

This method is advisable because better regulation is obtained with the Current control set at the high end of the scale. However, where a wide current sweep, or where output in the zero to 10-microampere range is desired, the Current control can be set to any position on the scale.

2-6. LOAD CONNECTIONS. Certain precautions must be observed when the power supply is to be operated at low currents of 1.0 microampere to 10 microam-

peres and at high load voltages of 75 volts or more. To prevent deterioration of regulation at the load, the shunt resistance between the two inter-connecting lead wires must be greater than 100,000 megohms. Any two wires connected between the output terminals and a load will exhibit a leakage resistance. This resistance will depend upon the following:

a. Whether the two wires are twisted or separated.

b. Distance of separation if not twisted.

c. Insulation of the wires.

Leakage current will be present at any time voltage is present. This leakage current becomes significant as the load current becomes small. For example, if the load current is 10 microamperes and 0.1 percent regulation is desired, the leakage current should be less than 0.01 microampere (0.1 percent of 10 microamperes). To achieve this, with 100 volts across the load, leakage resistance must be greater than 10,000 megohms. Since a safety factor of at least 2 is desirable, the leakage resistance should be greater than 20,000 megohms.

2-7. EFFECT OF EXTERNALLY INDUCED RIPPLE. Ripple can be injected into the system by inadequate shielding of load and output lines. It should also be noted that ripple is normally greatest with the negative output grounded. When a spurious signal is coupled into the sample resistor by pickup, leakage, etc., the regulator amplifier maintains a constant voltage drop across the sample resistor. This means that the regulator must develop a sufficient counter signal at the output, and therefore through the load, to cancel the disturbing signal tending to vary the current through the sample resistor. Thus, considerable ripple through the load can be caused by small amounts of spurious signals injected into the sample resistor. This underscores the importance of adequate shielding of the negative output lead wire and, when indicated, of the load itself. Care should also be taken when interconnecting the power supply with ac line operated devices.

2-8. PROGRAMMED OPERATION. The output of the power supply can be programmed (remotely controlled) by means of an external resistor. A fixed resistor can be used to provide a fixed constant-current output, or a series of switch-selected resistors can be employed to provide discrete currents. In addition, non-linear potentiometers can be employed to provide various waveforms.

For programmed operation, the Range Selector switch is placed in the REM position and a resistor is connected between the REM and — binding posts. The programming constant is more easily expressed in conductance than resistance. For this power supply, the programming constant is 200 micromhos per milliampere of output current with the Current control set at maximum. Specifically, 5,000 ohms is 200 micromhos so that a 5,000-ohm resistor allows for a 1.0-milliampere output. Adding another 5,000-ohm resistor in parallel allows for an additional 1.0-milliampere output, making a total of 2.0 milliamperes. Programmed operation is illustrated in Figure 2-1.

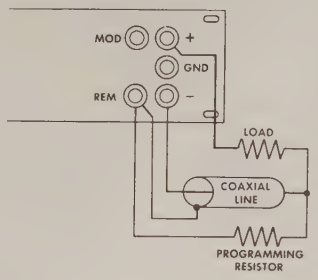


Figure 2-1. Programmed operation.

Because the load current also flows through the programming resistor, it is not necessary to run two lead wires to the — binding post if the programming resistor is physically located near the load. A common negative line to both the load and the programming resistor will suffice. However, because the — binding post is also the sensing point, the negative line must be well shielded by connecting one end of the shield to the REM binding post.

It is necessary to use a programming resistor of sufficient power rating. The actual wattage is given as power dissipation in watts equal 5 times the load current in amperes. A safety factor of at least 3 to 1 is recommended.

2-9. CONVERSION TO CONSTANT-VOLTAGE OUTPUT. This power supply can be converted to constant-voltage output in either of two ways. The first method requires external connections as shown in Figure 2-2 and provides an output as low as 5 volts with regulation of 0.05 percent. The second method requires internal reconnections as shown in Figure 2-3 but permits an output down to zero volts.

For external conversion to constant-voltage output, see Figure 2-2 and perform the following procedure:

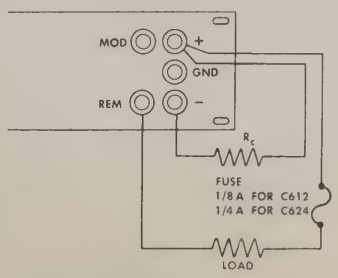


Figure 2-2. Constant-voltage conversion, external connections.

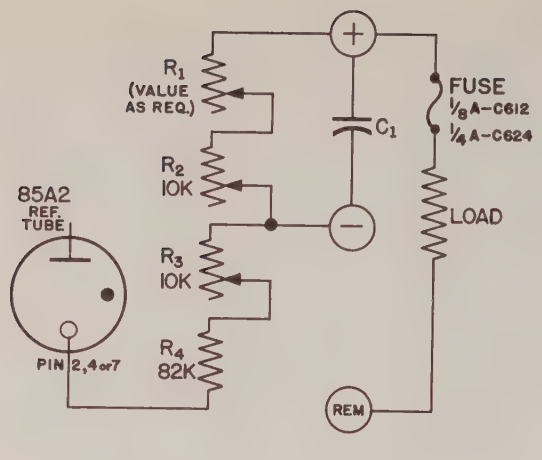


Figure 2-3. Constant-voltage conversion, internal reconnections.

a. Set the Range Selector switch to MA X1 1. (Lower ranges may be used.)

b. Set the Current control to the extreme clockwise position.

c. Select a control resistor of appropriate value for the desired output voltage. The resistance value is determined by the constant 1,000 ohms-per-volt output, if the Range Selector switch is set to MA X1 1. The output voltage is equal to the value of the selected resistor divided by 1,000 and added to the Current control setting (5 volts in this case).

d. Connect the resistor between the + and — binding posts.

e. Connect one end of an appropriate fuse to the + binding post.

f. Connect the load between the free end of the fuse and REM binding post.

g. The output voltage may be varied by adjusting the Current control or by changing the value of the control resistor.

For internal conversion to constant-voltage output, see Figure 2-3 and perform the following procedure:

a. Remove the top and bottom covers.

b. Locate pin 2, 4, or 7 on the socket for reference tube V4.

c. Connect one end of an 82,000-ohm, 1.0-watt resistor (R4) to the aforementioned pin. The quality of this resistor depends on the particular requirements. In many applications a carbon type resistor will suffice. For more stringent stability requirements, a wirewound type resistor should be employed.

d. Connect one end of a 10,000-ohm potentiometer (R3) to the free end of resistor R4.

e. Connect the arm of potentiometer R3 to the — binding post.

f. Connect potentiometers R1 and R2 in series as shown in Figure 2-3. These potentiometers will serve as output voltage controls. The total series resistance determines the zero-to-maximum output voltage in a control ratio of 1,000 ohms-per-volt output. Thus, with 10,000 ohms for R2 and 100,000 ohms for R1, the maximum output voltage of the power supply is 110 volts; similarly, 10,000 ohms for R2 and 200,000 ohms for R1 develops a maximum output of 210 volts. It should be noted that the choice of the resistance value for R1, and therefore of the maximum output voltage, is limited by the voltage compliance rating of the power supply. In addition, if the full current capability of the power supply is desired, the maximum output voltage must not exceed the minimum voltage compliance rating.

g. Connect capacitor C1 between the + and — binding posts. The value of this capacitor should be appropriate for the desired ripple level and programming speed. In general, a reduction in capacitance value denotes higher programming speed but larger ripple.

h. To calibrate the power supply to the exact 1,000 ohms-per-volt output control ratio (programming constant), set potentiometers R1 and R2 for maximum resistance. Turn the power supply on and adjust the resistance of R3 for rated output voltage as indicated on an external voltmeter.

In operation, the Range Selector switch is placed in the REM position and the Current control is set at zero. The load is connected between the + and REM binding posts. Coarse output adjustment is made with potentiometer R1, fine adjustment with potentiometer R2. These potentiometers now constitute the local voltage controls. For remotely programmed operation, potentiometers R1 and R2 can be connected from a remote control point.

2-10. VOLTMETER. The front panel Voltmeter does not affect the output impedance of the power supply. It indicates the voltage drop across the load within ±2% plus the voltage set by the current control.

2-11. MODULATION. The maximum modulation frequency for which this power supply has been tested is 10 kc. Input is applied between the REM and MOD binding posts. The source of modulation should have dc isolation if its output impedance is more than 1,000 ohms. The maximum permissible amplitude of modulation is limited by the voltage on the reference grid (pin 2) of balanced input detector V6, which is determined by the Current control setting. Exceeding the limits will cause progressive loss of control by the

current regulation system. At maximum Current control position, do not exceed 6 volts peak-to-peak signal input. Maximum modulation is permissible at a current control setting of 0.8 of maximum. At this point 8 volts peak-to-peak is permissible. The permissible input decreases proportionately to zero at the low end of the Current control scale. Non-linear modulation signals should conform to the peak-to-peak values cited above. During any portion of the modulating signal, none of the ratings of the unit should be exceeded.

2-12. VOLTAGE LIMITER. The purpose of a voltage limiter on a constant-current power supply is to permit control of the voltage applied to the load, preventing an uncontrolled rise in voltage above a particular value. A constant-current power supply, by definition, maintains the load current constant, but increases its voltage to the load as the load resistance rises.

In many applications it is desirable to limit the available voltage at some particular value, and this is the function performed by the limiter. It should be noted, however, that with the voltage limiter adjusted to a particular value, a rise in load resistance above a certain point, namely the "knee" of the EI curve, will result in a decrease in current from the output setting of the power supply. Above this point, in effect, the power supply reverts to constant-voltage, but with only moderate regulation. In general, the quality of the amplifiers within the regulation system of the power supply determines the sharpness of the "knee".

SECTION 3
CIRCUIT DESCRIPTION

3-1. GENERAL. This section describes the circuitry used in the Regatron Constant-Current Power Supply. The following discussions relate directly to the schematic diagram, located in the rear of this instruction manual.

3-2. BLOCK DIAGRAM DISCUSSION. Basically, the power supply can be divided into 7 circuit groups, all of which are interconnected as shown in figure 3-1. The basic function of these circuits is to maintain a constant voltage drop across the fixed sample resistor, which is connected in series with the external load. Because the voltage across the sample resistor remains constant, the current through the resistor, and consequently through the load, also remains constant. The balanced input detector compares the voltage across the sample resistor with a stable reference voltage. Any difference causes an error signal to appear at the output of the detector. This signal is amplified and then applied to the series amplifiers to readjust their operating conditions, thus changing the current in the sample resistor, and consequently in the load, until the error is virtually reduced to zero.

3-3. BALANCED INPUT DETECTOR. Tube V6 is employed as a balanced input detector. Pin 2, the reference grid, is connected to the arm of Current control R12, and pin 7, the sampling grid, is connected to the arm of Range Selector switch S4. Any voltage difference between grids is amplified and appears at the output plates as an error signal. Avalanche (Zener) diode CR4 maintains a stable 5-volt drop across the Current control. The Range Selector switch connects the appropriate sample resistor into the circuit for each current range. Regulated plate voltage is taken from VR tube V2, and the cathodes are returned through resistor R15 to —150 volts regulated by VR tube V3. NULL control R14 permits setting of the balanced input detector to zero difference between grids. Capacitor C9, resistor R55, and diode CR12 prevent the unit from being triggered into a stable on condition (maximum output voltage). Capacitor C4 and

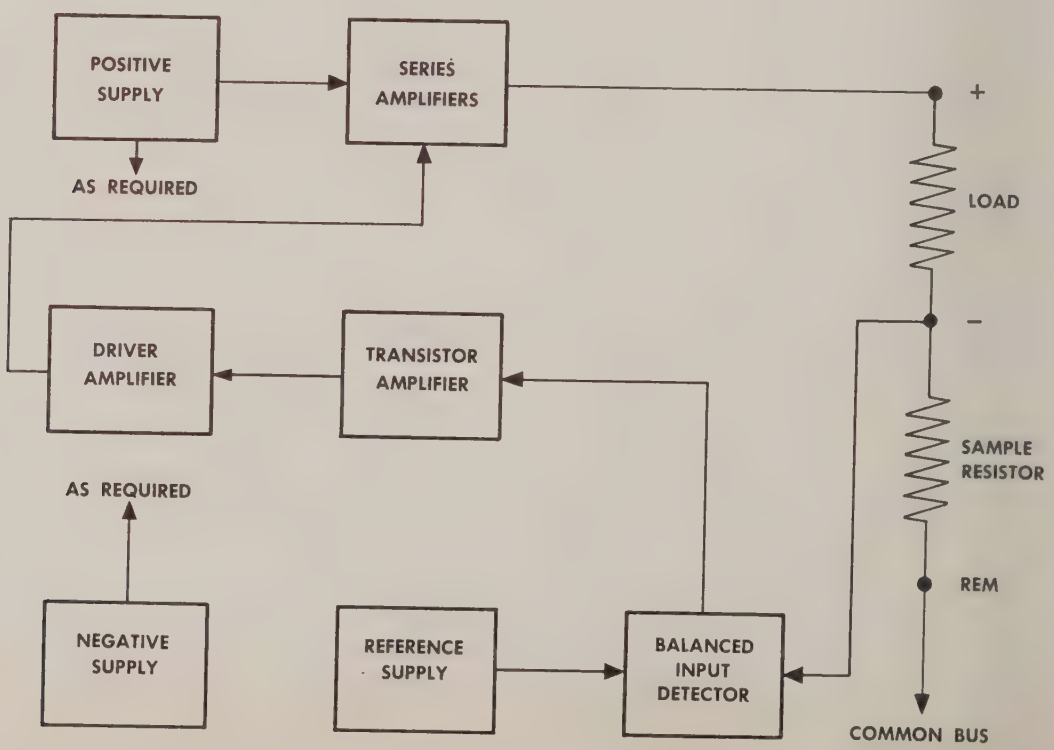


Figure 3-1. Block diagram.

INSTRUCTION MANUAL CHANGE
CONSTANT-CURRENT POWER SUPPLY
MODEL C612A, C6[illegible]A
(Code D962)

[illegible] to correct the loop characteristics of [illegible]er.

[illegible]ragraph 3-4. Capacitor C9 and resistor R55 also correct loop characteristics of the regulator amplifier.

[illegible]. The power supply has been designed to work [illegible]t.

resistor R49 serve as a filter to prevent any ac components from appearing on the reference grid.

3-4. TRANSISTOR AMPLIFIER. The error signal from the balanced input detector is applied to transistors Q1 and Q2. This transistorized amplifier stage is necessary to drive the second amplifier at a negative dc voltage. Since the error signal from the difference detector fluctuates around a positive dc base, it is necessary to convert the base to negative dc. This must be accomplished by direct-coupled means. Because PNP transistors use a negative collector voltage, they serve as effective direct-coupling devices in this application, and also introduce gain.

3-5. DRIVER AMPLIFIER. The second amplifier, V5, is a high gain amplifier from which the error signal is applied to the control grids of the series amplifiers. Because the power supply has been designed to start at a very low output, the output of the driver amplifier must be driven to approximately —45 volts to cut off the series amplifiers. This is accomplished by returning the cathode of V5 to —85 volts regulated by VR tube V4 so that sufficient voltage remains across the tube when the cutoff voltage is reached.

3-6. SERIES AMPLIFIERS. Paralleled beam power pentodes V7 and V8 are triode connected and are employed as series amplifiers or variable conductances. Their control grids are direct-coupled to the output of the second amplifier, V5. Any error voltage at the grid varies the conductance of these tubes. Thus an increase in the error voltage will cause the conductance of the series amplifiers to decrease. Since the series amplifiers are connected in series between the unregulated positive supply and the positive output to the sample resistor, the voltage drop across the tubes will increase, resulting in a decrease in the available output voltage and, consequently, a decrease in the current through the sample resistor. Likewise, a decrease in the error voltage will cause a corresponding increase in the conductance of the series amplifiers and, consequently, an increase in the current through the sample resistor.

3-7. POSITIVE SUPPLY. Transformer T1 supplies stepped-up voltages for all the rectifiers, and filament voltages for all the electron tubes in the power supply. The positive supply uses silicon diodes CR8 through CR11 in full-wave rectification, with filtering provided by resistor R52 and capacitor C2. This supply delivers unregulated positive voltage for the plates of the series amplifiers, and positive service potential for the plate of the driver amplifier and control grids of the series amplifiers. The rectified and filtered voltage is also applied through resistor R5 to VR tube V2 so that a pre-regulated stepped-down voltage is obtained for the plates of the balanced input detector and common emitters of the transistorized amplifier.

3-8. REFERENCE SUPPLY. The pre-regulated voltage is further dropped by resistor R10 and stabilized at approximately 5 volts by avalanche (Zener) diode CR4 to serve as the reference voltage for the balanced input detector. CAL control R11 permits calibration of the control system to a precise output current based upon the exact potential across CR4. It also permits periodic recalibration to eliminate error resulting from aging of CR4 and associated components.

3-9. NEGATIVE SUPPLY. The negative supply employs a half-wave rectifier system consisting of silicon diodes CR1, CR2, and CR3. The output of the rectifier is filtered by capacitor C1, dropped to —150 volts by resistor R1, and pre-regulated by VR tube V3. The negative potential is then dropped to —85 volts by resistor R2 and further regulated by VR tube V4. The regulated negative voltages are employed in the return circuits for the balanced input detector, transistor amplifier, and driver amplifier to increase their over-all operating range. Capacitor C3 serves to prevent any high frequency ac components generated by the VR tubes from appearing on the input grid of the driver amplifier.

3-10. FILAMENT REGULATOR. The filaments of the balanced input detector, V6, are regulated by a transistorized circuit which includes power transistor Q3 and signal transistors Q4 and Q5. Regulation of the balanced input detector tube filaments is necessary because the characteristics vary greatly over the operating range created by line input variations. The filament regulator uses transistor Q5 as an error detector with its emitter referenced to the voltage across avalanche diode CR6. Any error signal is applied to transistor Q4 which drives series transistor Q3 in a manner such that the error is reduced toward zero. The regulated output voltage can be adjusted over a small range by potentiometer R42.

3-11. VOLTAGE LIMITER. On models so equipped, the voltage limiter permits control of the maximum voltage available for application to the load. It incorporates a bridge-like sensing configuration similar to that utilized in Electronic Measurements voltage regulated power supplies. Resistors R59 and R60 (connected in parallel) function as the reference resistor. Potentiometer R57 permits calibration to rated maximum voltage. Potentiometer R56 is the LIMITER VOLTS control. It should be noted that the value of R56 is somewhat higher than is required to develop the rated maximum compliance. The explanation is that the value of R56 is selected to develop the full voltage which the power supply is capable of providing; this is, accordingly, somewhat higher than the rated maximum compliance.

Tube V9 functions as a high input impedance cathode follower. The control grid (pin 2) of this tube is connected at the junction of potentiometers R56 and

R57. The signal at the cathode (pin 3) follows the voltage fluctuations sensed at the grid in an almost 1:1 correspondence, and this signal is applied to the emitter of transistor Q6. The base of the transistor is connected to the REM binding post through current limiting resistor R52. The transistor compares the voltage at the REM binding post with the voltage sensed at the junction of the LIMITER VOLTS control (potentiometer R56) and the fixed reference resistor (R57, R59, and R60 in series parallel connection). The resultant collector signal is applied to the grid of tube V9, the cathode follower output of which is connected to the control grid of high gain amplifier V5.

3-12. CHOPPER STABILIZER. On models so equipped, the chopper stabilizer continuously corrects for zero offset in the balanced input detector, thereby eliminating output drift from this cause. Connected across the grids of balance input detector V6, the chopper stabilizer continually samples the offset at grid 2 (pin 2), chops it to produce a square wave, amplifies, rectifies, and filters it, and applies the resulting correction signal to grid 1 (pin 7) to reduce the net offset to a vanishingly small value. With chopper stabilization, the stability of the power supply is thereby improved as indicated in the Table of Specifications, paragraph 1-3.

SECTION 4
MAINTENANCE

4-1. GENERAL. This section contains normal adjustment procedures, a trouble shooting table, voltage and resistance charts, and parts location illustrations. Attention is called to the Warranty under which this equipment is sold, located on the front inside cover of this instruction manual.

4-2. NULL ADJUSTMENT. If any component in the control circuitry of the power supply requires replacement, check the null balance of the balanced input detector. This procedure is as follows:

a. Connect a jumper between the + and — output binding posts.

b. Set the Range Selector switch to MA X1 1, and rotate the Current control to the extreme clockwise position.

c. Connect a voltmeter, set to the 0-1 VDC range, between the — and MOD binding posts. This is also the chopper output for those units equipped with chopper stabilization.

d. Set the DC switch to the on (up) position.

e. Adjust the NULL screwdriver adjust control until the voltmeter indicates zero.

4-3. CALIBRATION. Calibration of the output current range settings is necessary when VR tube V4, avalanche (Zener) diode CR4, or any associated voltage divider resistor is replaced. Calibration procedure is as follows:

a. Set the Current control to the extreme clockwise position.

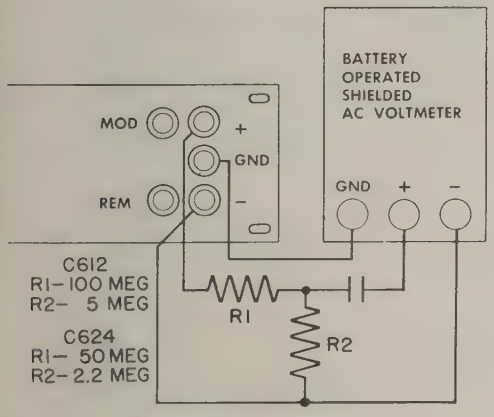
b. Connect an accurate, high input impedance voltmeter between the REM and MOD binding posts.

c. Adjust the CAL screwdriver adjust control for a 5-volt indication on the voltmeter.

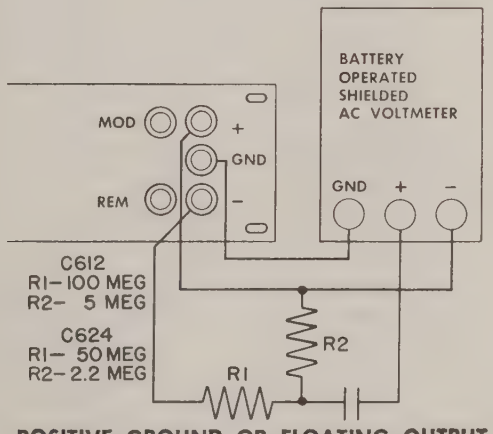
NOTE

The accuracy of calibration will depend upon the accuracy of the voltmeter in use. Since the tolerance of the range and sample resistors is ±1%, a ±2% meter will result in a maximum tolerance of ±3% of the output current range settings (at maximum Current control position).

4-4. RIPPLE MEASUREMENT. Figure 4-1 illustrates the correct method for measurement of ripple in the output of the power supply. Lead wires should be as short as possible. The voltmeter should be com-



NEGATIVE GROUND



POSITIVE GROUND OR FLOATING OUTPUT

PROCEDURE:

a. Record rms voltage.

b. With the input impedance of the rms voltmeter known, the current ripple is given by

$$I_R = \frac{V_R}{Z_1}$$ where Z_1 is the impedance of the following:

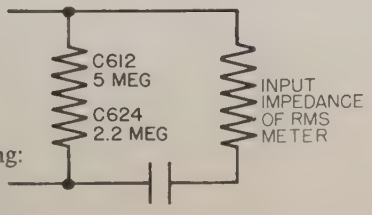


Figure 4-1. Method of ripple measurement.

pletely shielded and battery operated to avoid the injection of extraneous ripple. The load and sample resistor values are selected to produce the minimum compliance voltage in accordance with the voltage compliance graph, figure 1-2, with the Range Selector switch set to uA X10 2.2 and the Current control at maximum. These values should change appropriately to develop the same compliance for measurements at other Range Selector switch settings. The value of the load resistor equals the minimum compliance voltage divided by the Range Selector switch setting. The value of the sample resistor is calculated for a 5-volt drop. In the case of a 50-volt compliance, the load-to-sample resistor ratio will be 10:1; for 100 volts, 20:1.

4-5. FILAMENT REGULATOR ADJUSTMENT. Connect a voltmeter between pins 4 or 5 and 9 of tube V6, or between pin 4 or 5 of tube V6 and the positive lug of capacitor C7. Adjust potentiometer R42, located on the filament regulator chassis, until the voltmeter indicates between 5.8 and 6.0 volts.

4-6. TROUBLE SHOOTING TABLE. Listed in figure 4-2, are the several possible symptoms of troubles, with their probable causes and remedies. The table is intended as a brief guide in trouble shooting. It is best employed in conjunction with the voltage and resistance tables, parts location illustrations and schematic diagram, particularly when more obvious causes of malfunction have been eliminated and the fault is presumed to lie somewhere in a detailed circuit defect.

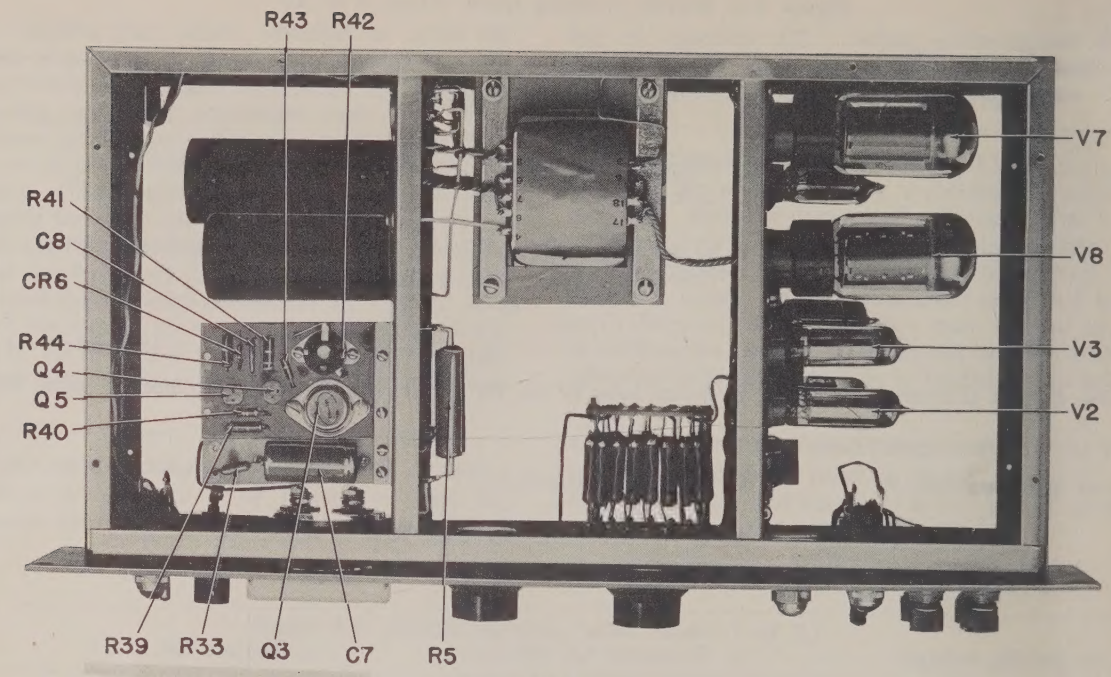
4-7. VOLTAGE AND RESISTANCE TABLES. The voltages and resistances listed in figure 4-4, 4-5, and 4-6 are nominal, and may vary as much as 20 percent without causing difficulties.

Figure 4-2. Trouble shooting table. (Sheet 1 of 2.)

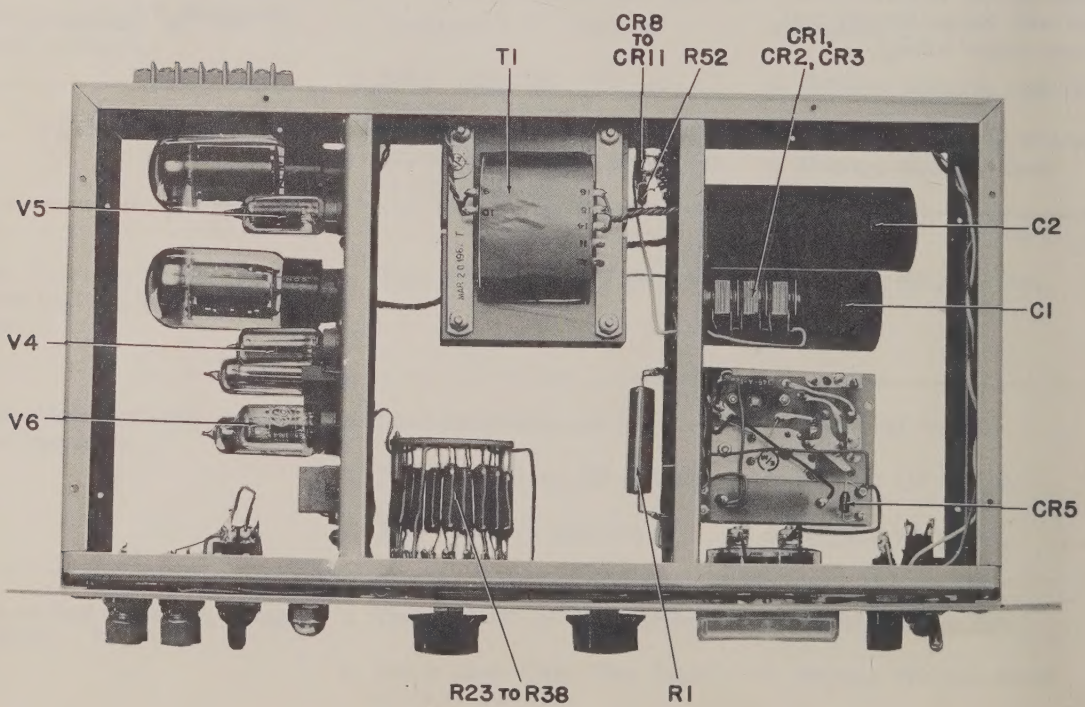
SYMPTOM	PROBABLE CAUSE	REMEDY
1. Unit inoperative or fuse F1 blows repeatedly.	a. Transformer T1 defective.	a. Replace T1.
	b. Filter capacitor C1 or C2 shorted.	b. Replace defective capacitor.
	c. Silicon diode CR8, CR9, CR10, or CR11 shorted.	c. Replace defective diode.
2. Line regulation poor; erratic output traced to line input variations.	a. Tube V2, V3, or V4 defective.	a. Replace defective tube.
3. Loss of load regulation; voltage set at maximum.	a. Load connection open.	a. Reconnect load.
	b. Transistor Q1 or Q2 defective.	b. Replace Q1 or Q2.
	c. Tube V5 or V6 defective.	c. Replace V5 or V6.
4. Loss of load regulation; voltage set at zero.	a. Transistor Q1 or Q2 defective.	a. Replace Q1 or Q2.
	b. Silicon diode CR8, CR9, CR10, or CR11 defective.	b. Replace defective diode.
	c. Tube V6 defective.	c. Replace V6.
	d. Filament regulator transistor Q6 defective.	d. Replace Q6.

Figure 4-2. Trouble shooting table. (Sheet 2 of 2.)

SYMPTOM	PROBABLE CAUSE	REMEDY
	e. Filament regulator diode CR5 defective.	e. Replace CR5.
	f. Silicon diode CR1, CR2, or CR3 defective.	f. Replace defective diode.
5. Low current delivery capacity.	a. Series tube V7 or V8 defective.	a. Replace defective series tube.
6. Loss of limiter control.	a. Tube V9 defective.	a. Replace V9.
	b. LIMITER VOLTS control R56 defective.	b. Replace R56.
7. Low limiting voltage.	a. Transistor Q6 defective.	a. Replace Q6.
8. Output current indications disagree with Range Selector and Current control settings.	a. Unit requires recalibration.	a. Adjust CAL control. Refer to paragraph 4-3.
9. Excessive ripple.	a. External load connections unshielded.	a. Refer to paragraph 2-7.



TOP VIEW



BOTTOM VIEW

Figure 4-3. Parts location.

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